Japanese Electricity Generation from Nuclear Technology and the Kyoto Agreement

by

Truong P. Truong[1] and Hiroshi Hamasaki[2,3]

[1] School of Economics, University of New South Wales, NSW 2052 Australia
[2] Energy and Environment Policy Group, Economic Research Centre, Fujitsu Research Institute (FRI), Tokyo, Japan
[3] Centre for Business Relationships, Accountability, Sustainability and Society, Cardiff University, Cardiff, UK

Abstract

We use the Nuclear Energy Agency and International Energy Agency (NEA/IED) data to modify the electricity production structure in the GTAP-E model to allow for electricity generation in Japan to be composed of nuclear and non-nuclear sources. We then use the model to conduct some policy simulations to analyse the effect of the implementation of the Kyoto Agreement on the Japanese economy, with and without the contribution from nuclear electricity. In the former case, we assume the output of electricity from nuclear technology to remain the same as in the reference case. In the latter case, we allow this share to respond to the rising electricity generating costs from non-nuclear means which results from the implementation of the Kyoto Agreement. We then compare the results from the two cases to look at the contribution from nuclear technology to the fulfillment of the Kyoto Agreement in the case of the Japanese economy.

1. Introduction

In 1997, the Kyoto Protocol, which defines emission reduction targets for major industrialised countries, was formulated in Kyoto, Japan. However, with the US and Australia not joining the Kyoto Protocol at present, the Kyoto Protocol covers only some 40% of global greenhouse gas emissions. Countries that ratified the Kyoto Protocol introduced or are about to introduce economic measures to meet the Kyoto target. For example, as part of its carbon reduction strategy the UK has introduced an emissions trading scheme (UKETS) in 2002 and the EU has already decided to introduce an EU wide emission trading scheme (EUETS) in 2005. However, the Japanese government has not introduced an effective climate change strategy, but rather adopted a "wait-and-see" approach. This cautious approach will be difficult to be maintained as negotiations toward second round commitments, post-Kyoto, are due to start by 2005. The Japanese government, therefore, needs to consider a more strategic approach in its climate change policy towards meeting the Kyoto target.

In this paper, we consider the effect of including nuclear power stations in the generation of electricity to meet the Kyoto target for Japan. We use the Nuclear Energy Agency and International Energy Agency (NEA/IED) data to modify the electricity production structure in the GTAP-E model to allow this to represent more accurately the electricity generation sector in Japan. We then use the model to conduct some policy experiments to analyse the effect of the implementation of the Kyoto Agreement on the Japanese economy, with and without the contribution from nuclear electricity. In the first experiment ("reference" case) , we assume electricity is generated from nuclear and non-nuclear sources in the same proportion as in the reference case. In the latter case, we allow this share to respond to the rising electricity generating costs from non-nuclear means which results from the implementation of the Kyoto Agreement. We then compare the results of the simulations to analyse the effect of the implementation of the Kyoto Agreement on the Japanese economy, with and without the contribution from nuclear electricity.

2. Model Description

2.1. GTAP-E with Technology Bundle Structure for the Electricity Sector

In this study, we use the GTAP-E model (Burniaux and Truong, 2002) which is the standard GTAP model (Hertel, 1997) but with energy substitution incorporated into the basic production structure (see Figure 1). GTAP stands for "Global Trade Analysis Project", and the GTAP model is a global computable general equilibrium (CGE) model, developed at the Center for Global Trade Analysis, Purdue University, USA, for use in global trade analysis. With energy-substitution incorporated, the modified GTAP-E model is often used for trade-environment analysis. In this paper, we further modify the GTAP-E model to allow for the disaggregation of the electricity generation sector into various 'technologies' such as 'coal-fired', 'gas-fired', 'oil-fired', 'hydro', 'nuclear', and 'others'. Each technology is assumed to produce a particular type of product (coal-electricity (ELYCoal), gas-electricity (ELYGas), etc.) using relatively fixed [1] input proportions. and then combine the different electricity outputs using a constant-ratio-of-elasticity-of-substitution-homothetic (CRESH) production structure[2]. This approach of disaggregating the production sturcture of an aggregate commodity such as electricity has been referred to as the "technology bundle" approach[3].

2.2. Database

In this study, we use 12 regions and 12 sectors aggregation based on the GTAP version 5.4 database. Details fo the aggregation are presented in Table 1.

[1] In the exteme case, the input proportions are entirely fixed (Leontief structure). In an intermediate representation, fuel inputs can be fixed, but there can be some substitution between some primary inputs.
[2] See Hanoch, G.. (1971) "CRESH Production Functions", *Econometrica*, 39, September, 695-712.
[3] See ABARE (1996).

Table 1 Categorisation of Sectors

	Description
Rice	Paddy Rice
Crops	Primary Agriculture & Fishing
Livestock	Livestock Products
Forestry	Forestry
Coal	Coal Mining
Oil	Crude Oil
Gas	Natural Gas Extraction
Oil_Pcts	Refined Oil Products
Electricity	Electricity
Omn	Minerals nec
En_Int_Ind	Energy Intensive Industries
Oil	Other Industries & Services

Table 2 Categorisation of Regions/Countries

	Description
CHN	China
IND	India
JPN	Japan
ASIA	Other Asian Countries
USA	United States
CAN	Canada, NZ and Australia
EU15	European Union
FSU	Former Soviet Union
CEU	Central and Eastern Europe
RoA1	Other Annex 1 Regions
LSA	Mexico & Latin America
ROW	Rest of the World

GTAP database does not provide separate database for each electricity generation technology. Thus to conduct this research, we have estimated the input requirements for different type of electricity generation technology based on study of the Nuclear Energy Agency and the International Energy Agency (NEA/IEA (1998).

Figure 1 Standard GTAP-E Production Structure

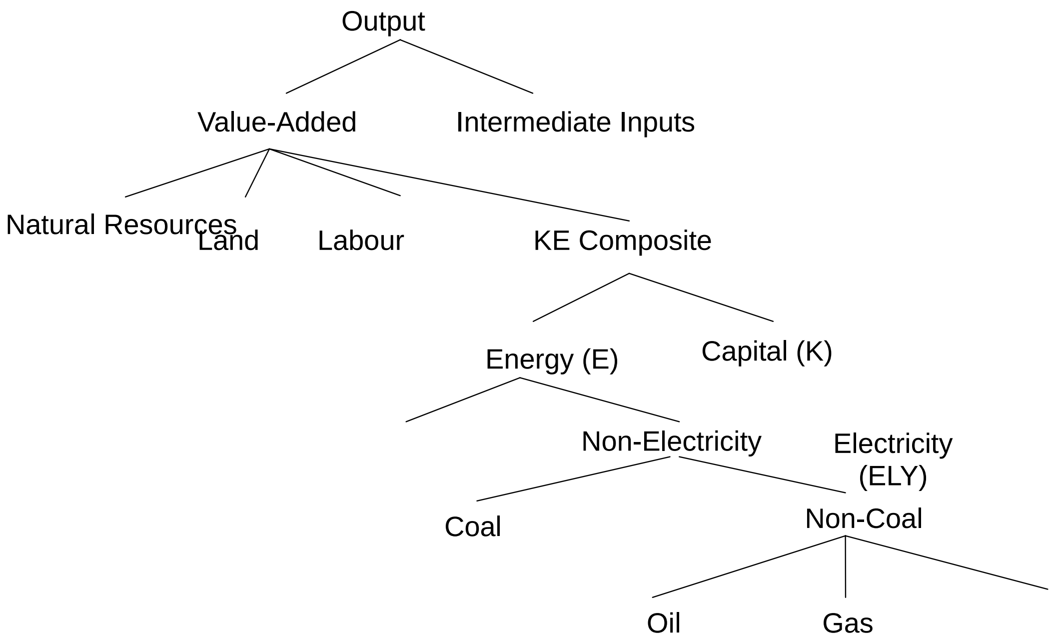
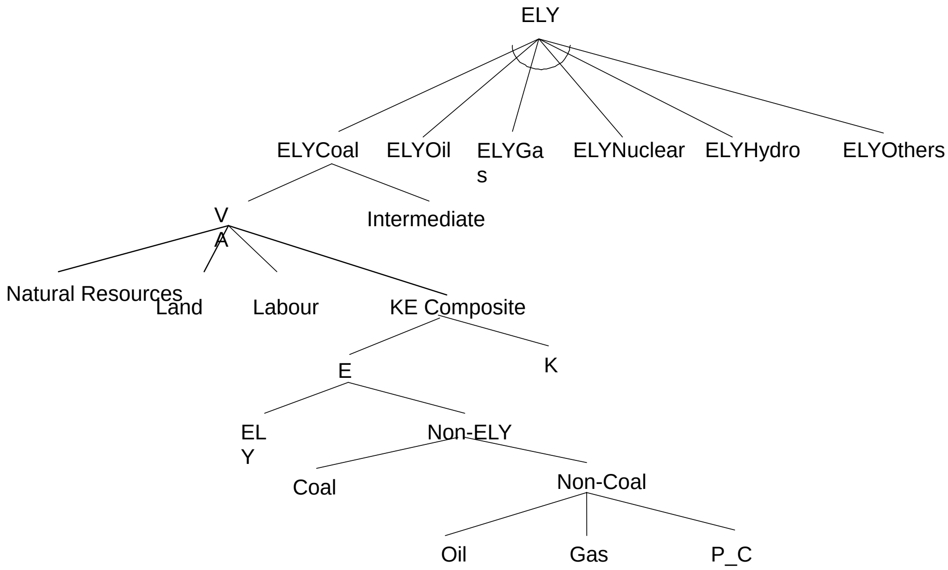


Figure 2 Production Structure for Electricity Sector



3. Simulation Experiments

In this research, we have carried out four static experiments. In the first experiment we reduce the emissions of CO_2 in Japan by –22.1 per cent to meet the Kyoto target. We let electricity by all technologies to grow as allowed by technology substitution within the model (assumed substitution elasticity is 30 which implies all technologies are near perfect substitutes). We call this experiment "Kyoto with normal electricity growth'. Next, we suspect that the high growth rates (70 to 90 percent) of hydro and other form (renewable) electricity as predicted by the model under this Experiment may be too high, and may not be sustainable by the limited natural and man-made resources available. Therfore, in Experiment 2, we restrict the growth of thee forms of electricity. We assume the 'worst case' scenario of 'no growth' in hydro and other forms of electricity in this Experiment 2, and we call this "Kyoto without Hydro and Other Electricity Growth'. In Experiment 3, we then consider the case when no growth in nuclear-powered electricity is allowed. Finally, in Experiment 4, we consider the extreme scenario when no nuclear electricity is allowed to grow while hydro and other forms of electricity are also remaining stagnant. The results of these four experiments are reported in Table 3.

From Table 3, we first note that the contribution of nuclear electricity to the objective of Kyoto compliance is substantial. Without nuclear electricity, the marginal abatement cost would increase from[4] \$46/ton of CO_2 to \$58/ton, or an increase of nearly 26 percent. This means nuclear electricity can help reduce the Kyoto compliance cost per ton of CO_2 of 26 percent, and this is more than the contribution from hydro and other forms of electricity (11 percent or a reduction from \$51/ton of CO2 to \$46/ton). In the worst case

[4] All costs are reported in 1995US\$.

scenario when nuclear, hydro, and other forms of electricity are not allowed to increase to substitute for fossil fuel-based electricity, the compliance cost can more than double, from $46/ton to $93/ton. Although we call this scenario 'worst case', it does not mean that it is 'unlikely'. From Table 3, it is seen that if Nucelar electricity is not to grow (Experiment 3), to make up for this loss of electricity output, hydro and other forms of electricity must increase substantially (by 165 per cent and 198 percent respectively). These are tall orders and may not be feasible in practice. As a result, it may turn out that if nuclear energy is to be limited, the 'worst case' scenario under Experiment 4 may as well be the result.

Table 3 also shows that while the effect of nuclear electricity on GDP growth may be small[5], its effect on per capita income growth is more substantial: if nuclear electricity is restricted, per capita income will decline by –0.53 per cent rather than just –0.22, and the figure could be as low as –0.80. Finally, the terms of trade is also worse under the 'no nuclear electricity' scenario: -0.32 as compared to 0.02. This is due to the fact that export price of Japanese goods will be much higher than import price due to higher price of electricity.

[5] In fact, GDP growth is slightly better under the scenario of 'no nuclear electricity' (-0.36%) as compared to the case of 'with nuclear electricity' (-0.39%). This is because employment growth and capital growth may be slightly worse under the 'with nuclear' scenario as compared to the 'no nuclear' scenario (see Table 3).

Table 3 Contribution of Different Electricity Technologies to Kyoto Compliance

	Experiment 1 Kyoto with normal electricity growth	Experiment 2 Kyoto without Hydro and Other electricity growth	Experiment 3 Kyoto Without Nuclear electricity growth	Experiment 4 Kyoto Without Nuclear, Hydro, and Other electricity growth
Marginal abatement cost (1995US$/ton of CO_2)	46.18	51.09	58.14	93.22
gCO2	-22.1	-22.1	-22.1	-22.1
qo("Ely")	0.19	0.04	-0.97	-2.76
qo("ElyCoal")	-72.8	-73.5	-75.6	-83.1
qo("ElyGas")	-4.6	2.9	16.1	77.7
qo("ElyOil")	-51.5	-51.6	-49.2	-52.7
qo("ElyNu")	59.0	78.5	0.0	0.0
qo("ElyHydro")	71.9	0.0	165.0	0.0
qo("ElyOth")	86.3	0.0	198.4	0.0
Electricity price	1.95	2.44	3.17	6.21
Real GDP growth	-0.39	-0.37	-0.36	-0.26
per capita income growth	-0.22	-0.20	-0.53	-0.80
Capital stock growth	-0.06	-0.06	-0.10	-0.17
Labour growth in:				
Rice production	-0.25	-0.27	-0.18	-0.18
Electricity generation	0.19	0.04	-0.97	-2.76
Japan's terms of trade	0.02	0.07	-0.32	-0.53

Note: gCO2: growth of CO2 emissions in Japan; pm("OIL"): import price of Oil into Japan; qo("Ely"): growth of Electricity output in Japan; qo("ElyCoal"): growth of Electricity generated from Coal, similarly for Gas, Oil, Nuclear ("Nu"), Hydro, and others ("Oth"); Japan's terms of trade = % change in world price of Japan export – % change in world price of Japan import.

4. Conclusion

In this study, we focused on the role of nuclear energy to meet the Kyoto target in Japan. We found that the contribution of nuclear energy to meeting the Kyoto target in Japan is substantial. While this may not take into account other environmental costs imposed by the use of nuclear fuel for electricity generation (this is an issue beyond the scope of this paper), the results in this paper will make an important contribution to the debate on whether nuclear energy should be used to address the issue of Kyoto compliance or global warming. On the *economic* cost side, the results from this paper should confirm the significance of nuclear energy in reducing this cost, and the order of magnitude of this contribution has been quantified in this study to be around 25 percent, or a quarter of the total compliance cost in the case of Japan.

Reference

Adams, Philip D. (2003), "Interpretation of Macroeconomic Results from a CGE Model Such as GTAP", paper prepared for the 2003 GTAP conference in Amsterdam.

Babiker, Mustafa, Hohn M. Reilly and A. Denny Ellerman (1999), "Japanese Nuclear Power and the Kyoto Agreement", Report #51, Joint Programme on the Science and Polciy of Global Change, Massachusetts Institute if Technology.

Burniaux, Jean-Marc and Truong Truong (2002), "GTAP-E: An Energy-Environment Version of the GTAP Model", GTAP Technical Paper No.16.

Dixon, Peter B. and Maureen T. Rimmer (2002), *Dynamic General Equilibrium Modelling for Forecasting and Policy –A Practical Guide and Documentation of MONASH-*, Contributions to Economic Analysis 256, Elsevier.

Hamasaki, Hiroshi (2004), "Japanese Strategy on Climate Change to Achieve the Kyoto Target with Steady Economic Development –An Investigation by Using the Dynamic Version of GTAP-E", presented at the 7th Annual Conference on Global Economic Analysis, Washington D.C., United States.

Hertel, Thomas W. (1997), "Global Trade Analysis –Modelling and Applications", Cambridge University Press.

Nordhaus W.D., and J. Boyer (2000), *Warming the World: Economic Models of Global Warming*, MIT Press.

NIE/IEA (Nuclear Energy Agency, International Energy Agency and Organisation for Economic Co-operation and Development) (1998), "Projected Costs of Generating Electricity Update 1998", IEA, Paris.

Paltsev, Sergey V. (2000), "The Kyoto Agreement: Regional Contributions to the Carbon Leakage", Center for Economic Analysis, Department of Economics, University of Colorado at Boulder Discussion Papers in Economics Working Paper No.00-05.